

# PATENT SPECIFICATION

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## (54) IMPROVEMENTS IN AND RELATING TO ARMOUR PIERCING PROJECTILES

(71) We, MALLORY METALLURGICAL PRODUCTS LIMITED, a British Company, of 78, Hatton Garden, London, EC1P 1AE, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to armour piercing projectiles and more particularly to armour piercing projectiles having the properties of hardness sufficient to penetrate armour plating and of ductility sufficient to pass through the fractured armour without shattering.

Desirably, a projectile, to be effective in the penetration of armour plating, needs to have

- (a) a high state of momentum, that is, a high velocity allied with large mass;
- (b) a hard nose overall in order to penetrate the armour, although it may have a soft first nose to help prevent shattering and prevent deflection; and
- (c) relatively high ductility and shatter resistance at the rear end of the projectile in order to pass through the fractured armour as a unit in a relatively unaltered condition.

Although requirement (a) requires a relatively high mass, the projectile may nevertheless be hollow and contain items such as detonators, explosives such as cordite, and one or more fuses and timing devices.

The high ductility requirement of the middle and rear part of the external shell of the projectile indicates the need for a relatively "soft" exterior as opposed to the

overall hardness required for the nose of the projectile. The shell will often have driving rings which, in conjunction with the rifling of a gun barrel, produces the necessary spin to keep the projectile on course.

It is an object of the present invention to provide a missile having a main body combining these somewhat conflicting physical characteristics in the form of an integral structure.

According to one feature of the invention an armour piercing projectile comprises a body having one region thereof formed from a sintered powdered metal composition possessing high overall hardness, high tensile strength and high modulus of rigidity and another region thereof formed from a sintered powdered metal composition possessing relatively lower overall hardness, higher ductility and lower tensile strength as compared with the composition forming said first region, said two compositions forming an integral structure, having been processed together by a common powder metallurgical method to form an integral bond between the two compositions.

One example of a composition which is capable of being heat treated to produce a material having very high hardness, high tensile strength and high modulus of rigidity comprises tungsten carbide cobalt, containing approximately 6 wt% cobalt. A further example of a composition capable of heat treatment under the same condition and usable as an alternative to the tungsten carbide cobalt composition, is one containing tungsten, nickel, iron and molybdenum. The relevant characteristics of these two compositions are typically:—

Material	Hardness	UTS	Elongation
WC,Co	74 Rockwell C	175 Tpsi	Nil
W, Ni,Fe,Mo	35—40 Rockwell C	70 Tpsi	9%

Another composition capable of heat treatment under identical conditions to give lower hardness, higher ductility and lower tensile strength is one containing tungsten, nickel and iron the corresponding characteristics being:—

	Material W, Ni, Fe	Hardness 25 Rockwell C	UTS 58 TPSI	Elongation 15%	
5	Each of the three compositions specified above has a tungsten content of 80 wt% or more and the two more ductile compositions exhibit high tensile strength and elongation. To fulfil the desired function it is considered that in such a projectile at least one of the component materials should have minimum tensile strength of 70 TPSI combined with at least 2% elongation. It is also considered necessary to provide a minimum tungsten content of 80 wt% to give a mass per unit volume of the order of at least 16.0 gms per millilitre.				65
10	Owing to the desirability for separate regions of the integral shell of the projectile to have differing properties but still to be part of a single entity, it is a further object of the present invention to provide a method whereby a unitary body structure may be produced using different mixtures of metals but intended to undergo the same process of metallurgical treatment, i.e. composition controlled atmosphere, pressure and temperature.				70
15	According to another feature of the invention a method of producing an armour piercing projectile comprises forming a rigid can of sheet metal or plastics material so as to have an interior shape corresponding to the desired final shape of the projectile with a generally pointed end but of greater dimensions, inserting into the can a deformable container of similar shape (hereinafter termed bag), the can and the bag each being open at the end remote from the generally pointed end, introducing into the bag a predetermined charge of a first composition of powdered metals and settling said charge, introducing into the bag a predetermined charge of a second composition of powdered metals and settling the second charge, sealing the deformable bag within the shaped can, placing the bag-can assembly in a pressure vessel and subjecting said assembly to pressure to compact the combined powder charge, removing the pressed compact from the bag and the can and sintering the pressed compact in the presence of a refractory oxide in a hydrogen or cracked ammonia atmosphere up to a temperature of 1500°C for a period sufficient to effect liquid phase sintering of both metal compositions, whereby the metal compositions are combined into a unitary structure.				75
20	The above method may be modified by inserting one or more tubes into the deformable bag prior to introducing the powdered metals. Where, for example, two concentric tubes are used a hollow projectile may be produced by charging the respective powder compositions one between the outer tube and the bag, the other between the two tubes,				80
25	with the inner tube empty. After so charging the bag the outer tube is withdrawn and the bag is sealed, the compact being pressed and heated in the conventional manner.				85
30	Preferably the outer tube is progressively withdrawn from the bag as the powders are filled into the same. Advantageously the mould may be vibrated during the filling operation. If it is preferred to enclose a core wholly within the outer shell of the projectile, the powder forming the shell should be first fed into the bag to form a bottom layer and then the tube or tubes are inserted with the two powders fed into the concentric spaces as previously described to a height less than the top of the can. If desired, a solid cylinder may of course, be used instead of the inner tube.				90
35	It will be obvious to those skilled in the art that hot pressing or hot isostatic pressing wherein compaction and heating are carried out in one operation may be used instead of separate pressing and sintering operations as described above. If desired more than two different powder compositions may be used.				95
40	Where isostatic pressing is employed this may be at a pressure of the order of 2000 atmospheres. It may also be advisable to interpose a pre-sintering operation prior to the final sintering to provide convenience in handling or to avoid shrinkage cracking.				100
45	The invention will be hereinafter more fully described by way of example with reference to the accompanying drawings of which Figure 1 shows a section of an assembly prior to pressing and Figure 2 shows a section of a finished sintered projectile.				105
50	Referring to Figure 1, a metal can 10 is lined with a deformable bag 11 formed for example of rubber. The interior shape of the can 10 is similar to that of the projectile to be produced but is of larger dimensions than said intended projectile.				110
55	A first powder mixture "A" is introduced into the nose 12 of the can as shown in Figure 1 which nose is of generally pointed shape, and the can is vibrated to settle the powder. A second powder mixture "B" is then introduced on top of the powder "A" as shown in Figure 1 and the can again vibrated to settle the powder "B". The filled can is then closed by a closure cap 13 after sealing the deformable bag 11.				115
60	The can, bag and the contents thereof are then subjected to pressure, for example, by placing the assembly in a pressure vessel and subjecting it to isostatic pressure in order to compact the combined powder charge. The pressed compact is then removed and subjected to a sintering operation in an atmosphere of hydrogen or cracked ammonia while placed on a bed of refractory oxide, up to a				120
					125

temperature of the order of 1500°C for a period sufficient to effect liquid phase sintering of both the powder compositions so that the metal alloy components exhibit the desired physical characteristics and are integrally connected as a unitary structure, as shown in Figure 2 although there is no sharp line of demarcation between the compositions "A" and "B". If necessary or desirable some mixing of the two powder mixtures at the interface can be effected before treatment.

While the projectile in the illustrated embodiment is shown as a solid structure it may of course be made in hollow form by the arrangement of an object of desired shape at the centre of the can as previously described. The arrangement of the different powder materials may take any configuration, depending on the intended purpose of the projectile. More than two powder mixtures may be used, if necessary, and an alternative pressing procedure such as hydraulic pressing with rigid tools can be adopted in place of isostatic pressing.

The powder mixture "A" may comprise either of the powder compositions hereinbefore specified having high hardness characteristics; another example is the proprietary product "Anviloy" (Registered Trade Mark) marketed by Mallory Metallurgical Products Limited. A composition suitable for use as powder mixture "B" is one containing tungsten, nickel and iron as previously specified or as an alternative a powder mixture containing tungsten, nickel and copper.

Two or more dissimilar tungsten base alloys may also be manufactured independently and then joined together by means of well known metal joining procedures such as silver soldering, welding by tungsten in inert gas with a suitable filler rod material or copper brazing in an inert or reducing gas atmosphere. Methods such as these do not provide the strength or quality assurance of the unitary pressing and sintering of two compositions in the one object but could fulfil the characteristics *a, b, c* set out in paragraph 2 hereof.

#### WHAT WE CLAIM IS:—

1. An armour piercing projectile comprising a body having one region thereof formed from a sintered powdered metal composition possessing high overall hardness, high tensile strength and high modulus of rigidity and another region thereof formed from a sintered powdered metal composition possessing relatively lower overall hardness, higher ductility and lower tensile strength as compared with the composition forming said first region, said two compositions forming an integral structure having been processed together by a common powder metallurgical method to form an integral bond between the two compositions.

2. An armour piercing projectile comprising a body having a plurality of component metal compositions made as an integral whole, at least one of the metal compositions containing at least 80% by weight of tungsten present as tungsten or a tungsten compound such as tungsten carbide and having a tensile strength characteristic of at least 70 tons per square inch and an elongation of 2% minimum, while another of the metal compositions is of higher overall hardness and tensile strength.

3. An armour piercing projectile according to claim 1 or claim 2 wherein the body is formed of two or more metal compositions of which at least two have a content of at least 80% by weight of tungsten present as tungsten or a tungsten compound such as tungsten carbide and at least one has a tensile strength characteristic of 70 tons per square inch and an elongation of 2% minimum, the two metal compositions being joined together to form an integral structure.

4. A projectile according to claim 1 wherein the metal composition of high overall hardness comprises tungsten carbide cobalt.

5. A projectile according to any of claims 1 or 3 or 4 as dependent on claim 1 wherein the more ductile material comprises a mixture of tungsten, nickel and iron or of tungsten, nickel and copper.

6. A projectile according to any of the preceding claims wherein the body thereof comprises a hollow structure.

7. A method of producing an armour piercing projectile which comprises forming a rigid can of sheet metal or plastics material so as to have an interior shape corresponding to the desired final shape of the projectile with a generally pointed end but of greater dimensions, inserting into the can a deformable container of similar shape (hereinafter termed bag), the can and the bag each being open at the end remote from the generally pointed end, introducing into the bag a predetermined charge of a first composition of powdered metals and settling said charge, introducing into the bag a predetermined charge of a second composition of powdered metals and settling the second charge, sealing the deformable bag within the shaped can, placing the bag-can assembly in a pressure vessel and subjecting said assembly to pressure to compact the combined powder charge, removing the pressed compact from the bag and the can and sintering the pressed compact in the presence of a refractory oxide in a hydrogen or cracked ammonia atmosphere up to a temperature of 1500°C for a period sufficient to effect liquid phase sintering of both metal compositions, whereby the metal compositions are combined into a unitary structure.

8. A method according to claim 7 wherein the pressure to which the can-bag assembly is subjected comprises isostatic pressure.

9. A method according to claim 8 wherein the isostatic pressure is of the order of 2000 atmospheres.
- 5 10. A method according to any of claims 7 to 9 wherein in order to produce a hollow projectile body two concentric tubes are introduced into the deformable bag prior to introducing the powdered metal compositions and subsequently the respective compositions are introduced one composition between the outer tube and the bag and the other between the two tubes, leaving the inner tube empty, the outer tube being withdrawn after or during the charging operation.
- 10 11. A method according to any of claims 7 to 10 wherein the can-bag assembly is vibrated during the charging steps.
- 15 12. A method according to claim 7, 8 or 9 wherein compaction of the charge by pressing or isostatic pressing is carried out simultaneously with the heating operation to produce sintering.
- 20 13. An armour piercing projectile substantially as hereinbefore described.
- 25 14. A method of producing an armour piercing projectile substantially as hereinbefore described with reference to the accompanying drawings.

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